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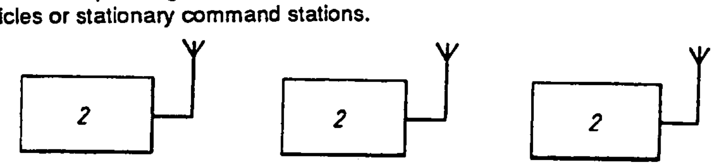
(54) **Frequency hopping radio communication system**

(57) A radio communication system includes a plurality of transceivers 2 intercommunicating by means of a frequency hopping system. The hopping schedule for a transceiver is statistically independent of the respective schedules of other transceivers, but the hop time intervals for each transceiver are synchronised with the respective hop time intervals of at least nearby transceivers operating in a statistically independent mode. The transceivers 2 may be in man packs, jeeps or other military vehicles or stationary command stations.



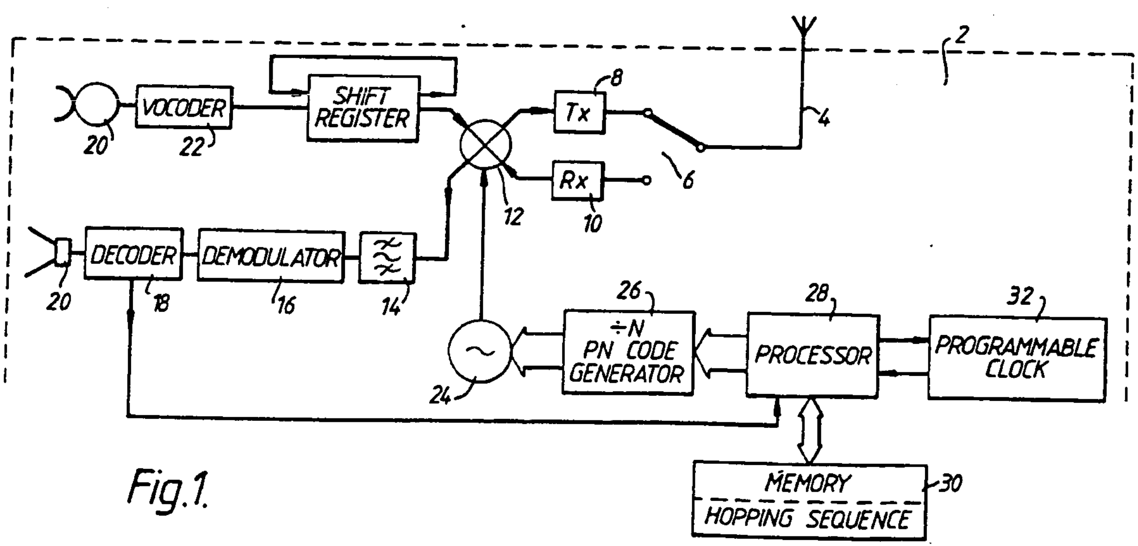


Fig.1.

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The print reflects an assignment of the application under the provisions of Section 30 of the Patents Act 1977.

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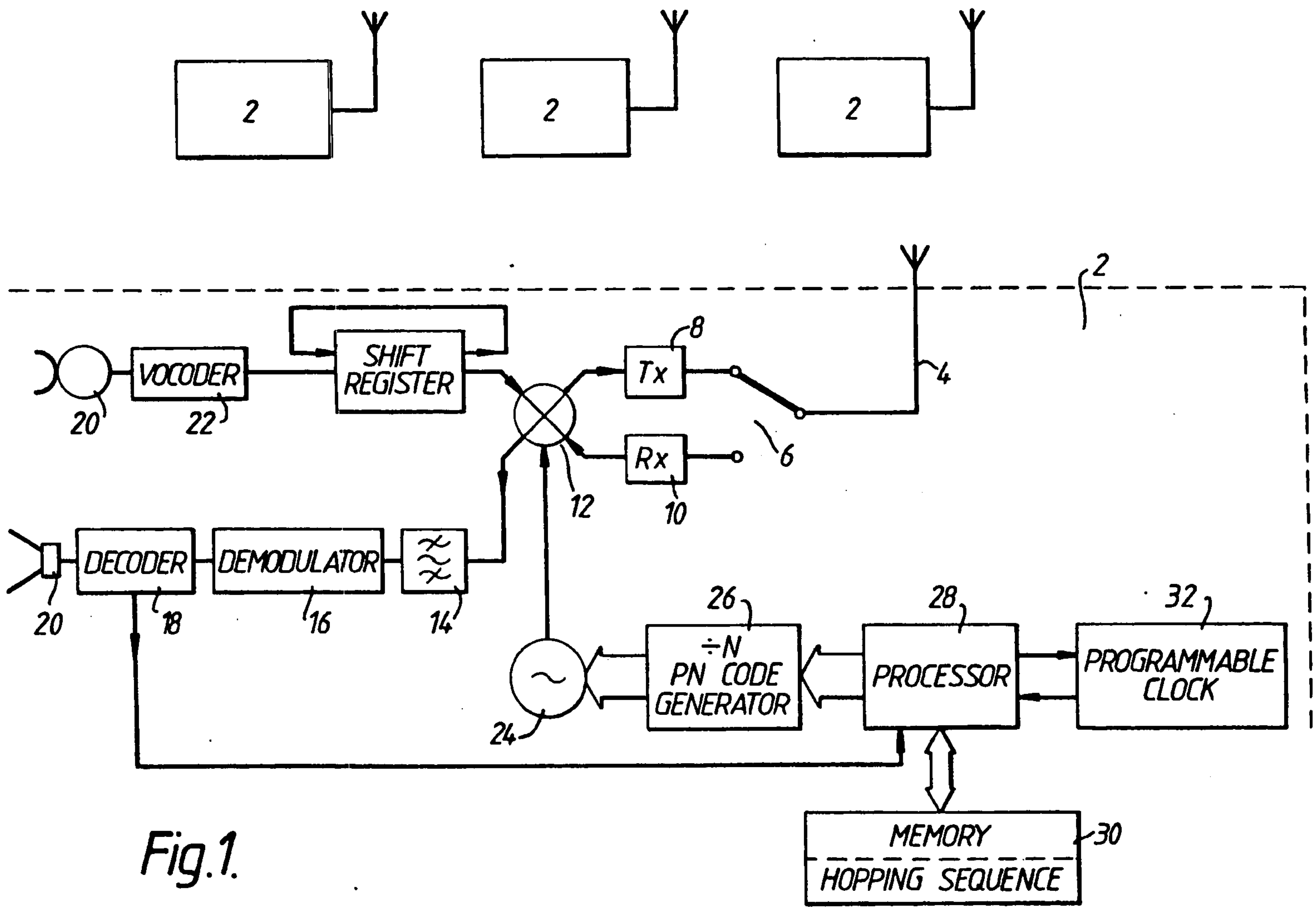
2
2
2
2
4
VOCODER
SHIFT REGISTER
Tx
Rx
8
10
6
12
20
22
DECODER
DEMODULATOR
20
18
16
14
24
÷N PN CODE GENERATOR
26
PROCESSOR
28
PROGRAMMABLE CLOCK
32
MEMORY
HOPPING SEQUENCE
30

Fig.1.

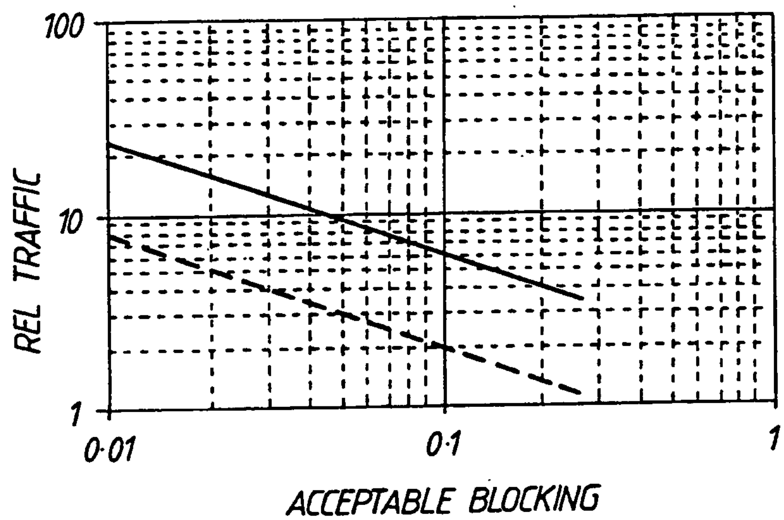

Fig.2.

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FREQUENCY HOPPING SYSTEM FOR CONGESTED ENVIRONMENTS

Field of the Invention

The present invention relates to a frequency hopping system for radio communication systems having multiple transceivers intercommunicating in congested environments.

Background Art

Military communications systems typically need to provide the following capabilities:-

Resistance to Interference (deliberate or otherwise).

Reliable operation in multipath fading.

Good spectral efficiency.

Simple frequency management.

Frequency hopping has been proposed as a means of providing resistance to interference. Essentially, single channel interference will only affect one of the channels visited in the pseudo random hopping sequence. Thus the probability of interference is equal to the number of single channel interferers divided by the total number of frequencies hopped over.

With a multiplicity of intercommunicating transceivers all operating by frequency hopping in the same band, some system self-interference will inevitably arise. Again, the probability of self-interference (assuming all sources at equal range) is equal to the number of active radios divided by the number of frequencies in the hopping set. The probability of interference is equal to the

proportion of frequencies blocked, provided the hop time of all radios are synchronised.

Systems for frequency hopping have been proposed in the past which carefully specify that no two radios whose transmission can illuminate a common area will ever transmit on a common frequency. This is known as orthogonal hopping. This is advantageous in theory but tends to be impracticable in reality for all but the most simple of systems.

Summary of the Invention

It has now been realised that the problems of self-interference in a deployment of frequency hopping radio networks which are hopping in statistically independent sequences are mitigated by the following factors:-

Interference is only received when two radios visit the same frequency simultaneously (this is the normally accepted interference rejection capability of frequency hopping).

Interference will only be received from equipments which are in range. This implies that frequency hopping inherently permits spatial re-use of channels or statistical parts of channels.

Interference is only received from radios which are currently transmitting.

Given that the average power of an interferer is strong enough to just cause interference on a wanted path, this interference will only arise when the fading conditions cause the wanted signal to fade below the unwanted.

For transmissions of speech at suitable hopping rate, the auditory effects of lost hops can be mitigated by detecting lost hops and replacing the speech with that contained in the previous hop. Up to 40% lost hops may be tolerated before speech becomes unintelligible.

Taken together, the above imply that statistically independent frequency hopping is highly robust even in a fairly congested environment.

An aim of the present invention is to provide a system which makes use of statistically independent frequency hopping, removing the requirement for complex frequency management algorithms to ensure that interference effects are minimised in the time and spatial domains, and by using modern technology reduced congestion is achieved without increasing system management overhead.

According to the present invention there is provided a frequency hopping system for congested environments which utilises at least one radio transmitter and receiver and a plurality of independent frequency hopping radio links which are conducted on statistically independent frequency hopping sequences.

According to an aspect of the present invention, each frequency hopping radio link is provided with a hop time which is synchronised with other frequency hopping radio link hop times.

According to a further aspect of the present invention a multiplicity of repeats of a voice transmission burst are sent to the receiver, to achieve a diversity effect at the receiver to reduce interference.

According to yet a further aspect of the present invention the receiver includes a diversity combining means which is used to receive the transmission of voice repeats to achieve enhanced interference and fading immunity.

The present invention provides a radio communication system including a plurality of transceivers intercommunicating by means of a frequency hopping system, wherein the hopping schedule for a transceiver is statistically independent of the respective schedules of other transceivers, but wherein the hop time intervals for each transceiver are synchronised with the respective hop time intervals of at least nearby transceivers operating in a statistically independent mode.

By synchronisation of hop time intervals, the statistical risk of self-interference is reduced since in each time interval, nearest neighbour transceivers will only be operating on one frequency, not two or more as would occur in an unsynchronised regime.

It is particularly preferred to further reduce the risk of self-interference to repeat each voice transmission burst two or more times in separate hop time intervals. In this way a diversity effect is produced by reason of the different carrier frequencies in each hop time interval, so that if one burst is interfered with, another burst may escape that interference. It may be sufficient to significantly reduce interference, even if the voice bursts are repeated in the same frequency, so that only time-diversity is achieved. Whilst it would in principle be possible to use spaced antennas to achieve space diversity, this may not be practical in many circumstances.

Whilst it would be possible to overcome the risk of self-interference in other ways e.g. by coding techniques, it has been found that repeating voice bursts reduces the risk of interference by a factor which matches the risk of self-interference in the situation where hop times are synchronised.

Brief Description of the Drawings

A preferred embodiment of the invention will now be described with reference to the accompanying drawings, wherein:-

Figure 1 is a block diagram of a preferred embodiment of the invention; and,

Figure 2 is a graph indicating the advantages occurring from the present invention.

Description of the Preferred Embodiment

Referring now to the drawings, Figure 1 shows a preferred embodiment of a radio communication system in accordance with the invention comprising a multiplicity of transceivers 2, which in a military environment may be embodied as man-packs, transceivers located in jeeps or other military vehicles or central or local command stations which may be stationary.

The transceivers shown are arranged to operate within one band of frequency, preferably in the lower VHF region, between 30 and 80 MHz. In a large system, there may be other classes of transceivers operating in other frequency bands. Each group of transceivers may consist of as few as 2 transceivers or as many as between 10 and 20 transceivers. Only one transceiver is permitted

to transmit at any time while the others are in receive mode. Each group operates in a frequency hopping mode wherein each transceiver of the group has the same frequency hopping sequence. Since there may other groups operating in different frequency sequences, the risk of self-inteference within the radio communication system arises.

Each transceiver 2 comprises an antenna 4 coupled via a two-way switch mechanism 6 to a receiver unit 8 and a transmitter unit 10. The units 8, 10 are coupled to a mixer 12 where the received or transmitted signals are mixed with a signal from a local oscillator 14. In receive mode, the resultant IF signal is fed through a band pass filter 14 to a demodulating unit 16, a decoding unit 18 and a loud speaker unit 20. The precise form of the demodulating unit 16 depends on the type of modulation employed, e.g. FSK or MSK. Similarly the decoding unit 18 depends on the precise type of voice encoding used. For military applications, a form of vocoding is normally used wherein the speech signal is encoded at a very low bit rate, 8 Kbits per second or less, and the speech patterns are reproduced by means of unit 18. On the transmit side, a microphone 20 provides an analogue speech signal to a vocoder encoding unit 22 which provides a low bit rate digital output to a circulating shift register 24, register 24 being arranged to provide to mixer 12, each coded burst of the voice signal a plurality or a multiplicity of times, so that each voice burst is transmitted a similar number of times.

The local oscillator 14 is a frequency synthesiser based on a phase lock loop and the division ratio of the loop is fixed by a pseudo random number generator 26. Generator 26 is controlled by a

processor 28 which has an associated memory store 30 and a programmable clock 32.

In operation of the system according to the invention, it is necessary in a start-up mode, initially to synchronise the clocks of the transceivers of all groups within the system. This can be done by any of a variety of well-known network control procedures wherein the transceivers are synchronised with one another. To this end, processor 28 receives control signals from decoding unit 18 and suitably adjust the timing of programmable clock 32.

Each memory store 30 of each transceiver within a single group has an identical set of hopping frequencies stored therein. Processor 28 controls pseudo random code generator 26 in dependence upon the number and values of different hopping frequencies so that generator 26 transmits to synthesiser 14 a pseudo random sequence of frequency division factors. Since all the transceivers within each group are synchronised, the pseudo random code generators of each transceiver in the group will operate in an identical manner. In this way, communication is enabled between transceivers in the group.

Because transceivers of other groups may be simultaneously transmitting at the same time, there is the risk of self-interference, but in accordance with the invention, since the hop time intervals of all groups within the system are synchronised, the risk of self-interference is reduced, even though the hopping schedules of the different groups are statistically independent. Further, the provision of circulating shift register 24 ensures that each voice burst is transmitted a plurality of times, the precise number depending on the risk of self-interference. It can be shown mathematically that it

is possible precisely to match the risk of self-interference by providing a plurality of repeats and this therefore reduces the risk of voice bursts being lost and a consequent degradation in system performance.

Demodulating unit 16, operates to evaluate each voice burst of a plurality of repeats of the burst and chooses that burst having the best signal to noise ratio as the best approximation to the burst. It would be possible where greater accuracy is required to employ maximal rate combining wherein the signal to noise ratio of each burst is evaluated and the repeats are added together in proportion to their signal to noise ratio. The problem here is that the voice bursts must be aligned in frequency and phase and a complex process of decryption before demodulation is required.

Referring to Figure 2, this depicts two slopes showing the relationship of traffic against acceptable blocking, relative to a conventional system (i.e. the horizontal line Rel. Traffic = 1). The higher illustrates operation of the invention in a system where modem data modem and voice codec technology have yielded a threshold improvement in basic capacity. The lower curve shows the performance obtained merely by applying the invention to existing technology.

Current practice for frequency hopping Combat Net Radio (CNR) is to hop over channels with a spacing of 25KHz to provide an average transmission rate of 16kbps. This is used to provide digitised voice using a standard low technology voice codec (usually 16kpbs CVSD - Continuously Variable Slope Delta Modulation).

Using modern modulation techniques (e.g. Continuous Phase Frequency Shift Keying with partial response) it is possible to provide an average transmission rate of 24kbps with improved error performance in noise over the existing non-coherent binary FM approach.

Moreover, voice codecs operating at 8kbps or less and providing better voice quality and equivalent error tolerance are also available (e.g. N Kingsbury's sub band coder).

Together these two technological advances means that within a single 25KHz RF channel, three voice channels could be transmitted.

This fact could be exploited in a simple way by reducing the bandwidth of each channel by a factor of three, thereby increasing the number of frequencies in the hopping set by the same factor and thus proportionately reducing the probability of interference. This is practical but undesirable for the following reasons:-

Reducing the channel bandwidth would tighten the requirement for transmission and reception frequency accuracy.

Nearly all of the existing sources of interference in the area where such a radio would be used operate with 25KHz spacing. Thus the probability of interference from these sources would not be reduced.

An alternative to reducing the transmission bandwidth for each hop is to repeat the same voice information on three successive hops and combine the information in the receiver in some suitable fashion. For all but the higher levels of congestion this has an even greater effect on interference probabilities than reducing the transmission

bandwidth. For any given acceptable level of interference this corresponds to an increase in the level of traffic which can be supported as illustrated in Figure 2.

The two slopes show the effect of repeats both for the case with and without the improvements due to technology for the case of triple repeats.

It also has other advantages. Repeating the transmission on three different frequencies is equivalent to triple path diversity and as such achieves a powerful improvement in resistance to multipath fading. At the frequencies at which CNR is currently and likely to be used (lower VHF), the wavelengths are relatively long resulting in relatively long fades in time. The diversity will greatly ease the problem.

The transmissions from the three repetitions can be combined in any of a number of the conventional approaches available for diversity combining, e.g.

Selection combining - in this case some measure in the receiver is used to choose the version of the transmission which either has, or is most likely to have, the fewest errors.
The error checking could be performed either by transmission of some suitable error protection coding added at the transmitter or by using some metric provided by the demodulator.

Maximal ratio combining - In this approach some measure (e.g. the Eb/No of the sync word) is used to assess the average Eb/No for each of the version. The versions are then frequency and phase aligned and added together in radios proportional to

their individual values of Eb/No. This is complex but would provide the best possible performance.

CLAIMS

1. A radio communication system including a plurality of transceivers intercommunicating by means of a frequency hopping system, wherein the hopping schedule for a transceiver is statistically independent of the respective schedules of other transceivers, but wherein the hop time intervals for each transceiver are synchronised with the respective hop time intervals of at least nearby transceivers operating in a statistically independent mode.

2. A radio communication system as claimed in claim 1 wherein each transceiver includes means for repeating each voice burst associated with a hop time interval a plurality of times.

3. A radio communication system as claimed in claim 1 including a plurality of groups of transceivers, each group operating in a frequency mode statistically independent of other groups, and the transceivers of each group being synchronised in terms of a hopping schedule, wherein in each group only one transceiver may transmit in any time interval.

4. A radio communication system substantially as described with reference to the accompanying drawings.

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